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ABSTRACT

Both the Rule Space Method (RSM) and the Neural Network Model (NNM) are techniques of statistical pattern recognition and classification approaches developed for applications from different fields. RSM was developed in the domain of educational statistics. It started from the use of an incidence matrix Q that characterizes the underlying cognitive processes and knowledge (attribute) involved in each item. The examinee's mastered/nonmastered states (knowledge state) for each attribute is determined from item response patterns. RSM uses the multivariate decision theory to classify individuals, and NNM, considered a nonlinear regression method, uses the middle layer of the network structure as classification results. Similarities and differences between the methods, and their supplemental characteristics when both are applied are discussed. This paper compares these approaches by focusing on the structures of NNM and knowledge states in RSM. An application of RSM is shown for a reasoning test in Japan. (Author/SLD)

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# A Comparison Study of Rule Space Method and Neural Network Model for Classifying Individuals and an Application

Atsuhiro Hayashi

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# A Comparison Study of Rule Space Method and Neural Network Model for Classifying Individuals and An Application

Atsuhiro Hayashi*

*Abstract* - **Both methods, Rule Space Method (RSM) and Neural Network Model (NNM) are techniques of statistical pattern recognition and classification approaches developed for applying from different fields; one is for behavioral and the other is for neural sciences. RSM is developed in the domain of the educational statistics. It starts from the use of an incidence matrix Q that characterizes the underlying cognitive processes and knowledge (Attribute) involved in each Item. Examinee's mastered/non-mastered states (Knowledge State) for each attribute is determined from item response patterns. RSM uses the multivariate decision theory to classify individuals, and NNM that is considered as a nonlinear regression method uses the middle layer of the network structure as classification results. We have found some similarities and differences between the results from the two approaches, and moreover the both methods have supplemental characteristics to each other when applied to the practice. In this paper, we compare the both approaches by focusing on the structures of NNM and on knowledge States in RSM. And finally, we show an application result of RSM for a reasoning test in Japan.**

## 1 Introduction

A Neural Network model was proposed for the purpose of modeling the information processing in person's brain in the 1940s. Neurons (nerve cell elements) are considered as the minimum composition unit of cerebral functions that entangled in complicated and organic manners. The model shows that all the logical reasoning can be described in a finite size of the number of neurons and connections. The model enables us to express acquisition of new knowledge from learned examples in the past, therefore it can be used to help to solve one of the weaknesses in constructing an AI (Artificial Intelligence) system. It is known that expressing knowledge acquisition in an AI system is extremely difficult.

On the one hand, Rule Space Method is a technique of clustering examinees into one of the predetermined latent Knowledge States (KS) that are derived logically from expert's hypotheses about how students learn. The method can be considered as a statistical testing technique of expert's hypotheses. These hypotheses are expressed by an item-attribute matrix (incidence matrix Q) where attributes are representing underlying knowledge and cognitive processing skills required in answering problems. A Knowledge State consists of mastered/non-mastered of attributes, and a list of all the possible Knowledge States can be generated algorithmically by applying Boolean Algebra to the incidence matrix Q. This method is fairly new but has lately started getting some attention because it is possible to provide diagnostic scoring reports for a large-scale assessment.

We have found there are similarities between the results from the two approaches, and moreover they have complementary characteristics when applied to the practice. In this paper, we discuss the comparisons of both approaches by focusing on the structure of the Neural Network (NN) and of Knowledge States in the RSM. And we show an application result for a reasoning test.

* Research Division, The National Center for University Entrance Examinations, 2-19-23 Komaba, Meguro-Ku, Tokyo, 153-8501, JAPAN. E-mail:hayashi@rd.dnc.ac.jp

## 2 Feed-Forward Neural Network Model

In spite of that the mathematical formulization of the Feed-Forward NN is simple, any nonlinear functions can be used by selecting deferent numbers of middle layers and connections between neurons. When we apply this technique to existing data obtained from learning processes, we can use this model to search for the strategy of any joint intensity between units.

From statistical point of view, NNs are nonlinear regression equation models. In this paper Feed-Forward NN is considered as a model-fitting procedure to estimate the optimum values of parameters in regression equations.

This procedure is called parameter estimation in statistics, but is called a learning algorithm in NN. One of the learning algorithms commonly used is Back Propagation (BP) that is a learning method by passing on errors to previous layers. BP is an adaptation of the steepest descent method to the NN field. This method has a reducible faculty of the convergence to the local minimum point.

## 3 Rule Space Method

RSM is a technique developed in the domain of the educational statistics. It starts from the use of an incidence matrix Q that characterizes the underlying cognitive processes and knowledge (Attribute) involved in each Item. It is a grasping method of each examinee's mastered/non-mastered learning level (Knowledge State, KS) from item response patterns. Up to now, the results of examinees' performance on a test are reported by total scores or scaled scores. However, if this technique is used in educational practices, it is possible to report which attributes each student mastered or non-mastered, in addition to his/her total scores. It is often true that the same total score may have several different Knowledge States. By reporting detailed information of his/her Knowledge State, learning can be facilitated more effectively than just providing total scores only.

## 4 Science Reasoning Test

The Science Reasoning Test (SR-Test) is an entrance examination test that measures the student's interpretation, analysis, evaluation, reasoning, and problem-solving skills required in the natural sciences.

Since we got the ACT's (American College Testing, Inc.) cooperation, we used one open-form of their ACT Assessment tests for our experimentation. The test is based on units containing scientific information and a set of multiple choice questions about the scientific information. Calculators are not permitted to be used for the test. The scientific information for the test is provided in one of three types of formats.

The first format, data representation, presents graphic and tabular material similar to that found in science journals and texts. The questions associated with these format measure skills such as graph reading, interpretation of scatter plots, and interpretation of information presented in tables. The second format, research summaries, provides students with descriptions of one or more related experiments. The questions focus upon the design of experiments and interpretation of experimental results. The third format, conflicting viewpoints, presents students with expressions of several hypotheses or views that, being based on differing premises or on incomplete data, are inconsistent with one another. The questions focus upon the understanding, analysis, and comparison of alternative viewpoints or hypotheses.

The Science Reasoning Test questions require students to use the scientific method to answer the questions. The students are required to recognize and understand the basic features of, and concepts related to, the provided information; to critically examine the relationships between the information provided and the conclusions drawn or hypotheses developed; and to generalize from given information to gain new information, draw conclusions, or make predictions.

## 5 Numerical Examples

We applied the RSM to a data of fraction addition problems, and got a tree structure of Knowledge State. We related RSM that derives the Knowledge State from an incidence matrix Q, to the Feed-Forward NNM. For that, we designed the network of the three-layer structure in which items were assigned to the input layer and Attributes were to the output layer. The Knowledge States in the RSM were considered to correspond to the middle layers of NNM. We applied several numerical examples to the both methods, and found close similarities in their results although they were not identical.

And we applied the RSM to a data of Science Reasoning Test of Japanese students. Figure 1 is the tree representation of the Knowledge State that shows the examinee's mastered/non-mastered learning level with the number of classified one on each class.

We'll show the more detailed result in the presentation.

## 6 Discussion and Conclusions

We investigated the relationship between the characteristics of the middle layer of NN and the Knowledge States in the RSM, and discussed their similarities and usefulness in supplements the weaknesses existing in the RSM.

It is well known that the composition of an incidence matrix Q in the RSM is a very laborious task, requires experts' intense cooperation. The experts identify attributes involved in each item and express them in an incidence matrix Q. It needs to investigate multiple numbers of solution strategies for each item. This is extremely hard work. If an examinee's mastering level (cluster) is known to some extent from past experiences, it is also possible to construct a network in which these clusters are assigned to the output layer of NNM. The middle layer drawn from this model is expected to correspond to Attributes. It may be possible to use this result for replacing a task analysis required in making an incidence matrix Q in RSM.

We plan to clarify the difference and similarities of the two models with numerical examples, or will get useful results to apply these methods for the SR-Test data and our real examination data.

## Acknowledgement

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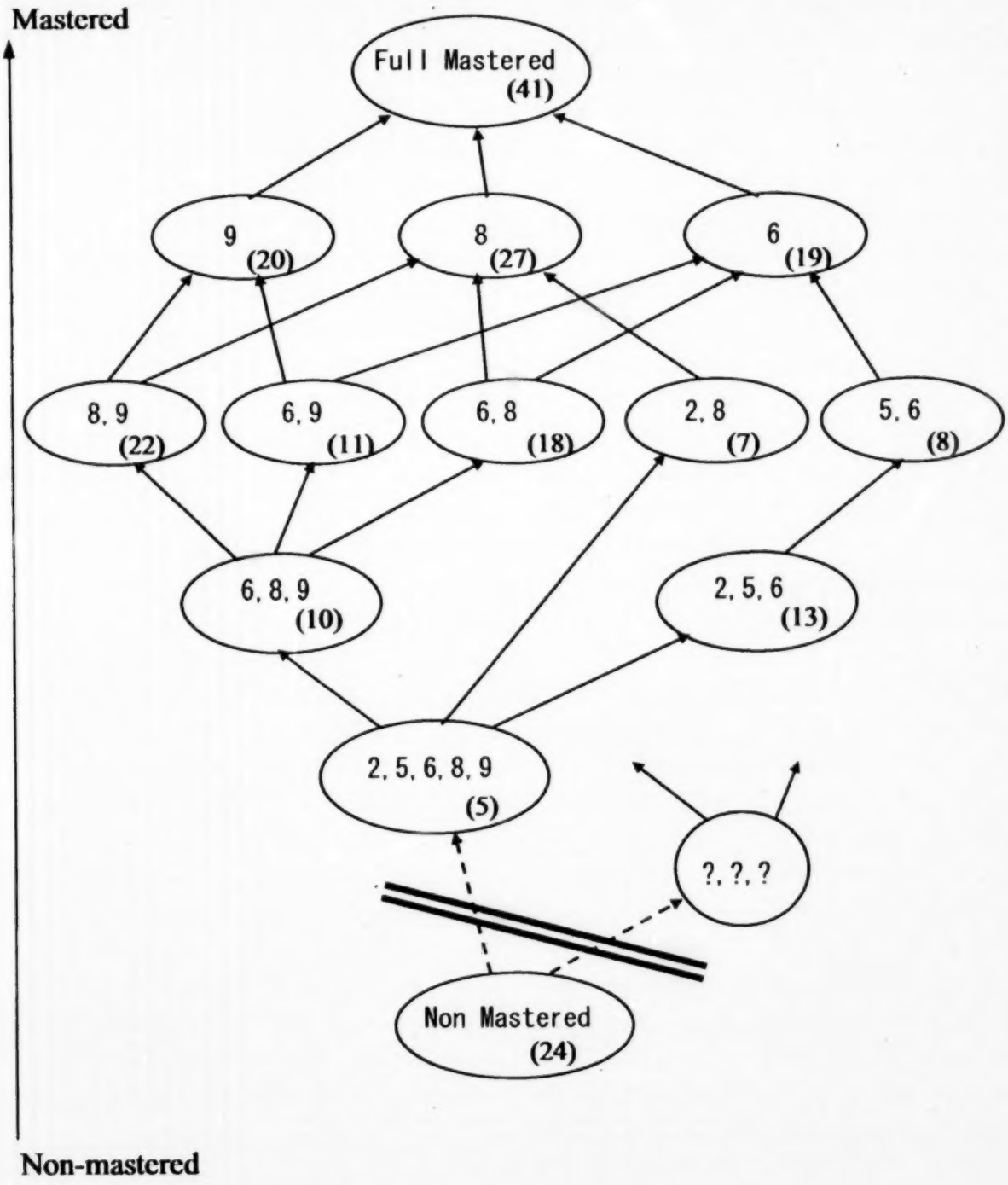


**Figure 1 : A tree representation of Knowledge States for the SR-Test data**

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